P.O.L.

RRS CHALLENGER

CRUISE 28/88

29 April - 14 May 1988

NORTH SEA SURVEY

SHAKEDOWN CRUISE

CRUISE REPORT NO.5

1989

PROUDMAN OCEANOGRAPHIC LABORATORY

NATURAL ENVIRONMENT RESEARCH COUNCIL

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ABSTRACT

This report describes RRS Challenger cruise 28/88, from 29 April to 14 May 1988, the shakedown cruise for the survey experiments of the North Sea Project.

The main objectives of the cruise were to prepare for the survey by testing the survey plans, by testing and gaining familiarity with the equipment and by obtaining additional information on which to base some of the experiments. Aided by fine weather all the objectives were met. The planned survey track was completed and shown to be feasible in good conditions, any fine tuning to the track will be determined on scientific grounds. All the major items of equipment worked well and familiarity with their operation was gained.

Along the cruise track continuous measurements of sea surface properties, of atmospheric inputs and of current profiles were recorded. At 164 sites along the track CTD profiles and water bottle samples (for nutrient and trace metal analysis, as well as CTD sensor calibration) were obtained. At 41 sites along the track cores were recovered with the SMBA multiple corer.

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SCIENTIFIC PERSONNEL

29 April - 14 May 1988

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T.J.	Moffat	Plymouth Polytechnic, Marine Studies
A.	Poole	Research Vessel Services
R.W.	Powell	Research Vessel Services
A.D.	Robinson	Research Vessel Services
A.C.	Upton	Essex University, Biology
J.	Watson	Scottish Marine Biological Association

29 April - 8 May 1988

G.F.	Bradshaw	Liverpool University, Oceanography
E.B.	Cooper	Research Vessel Services
D.J.	Hydes	Institute of Oceanographic Sciences, Deacon Lab.
G.W.J.	Miller	Research Vessel Services
R.J.	Parkes	Scottish Marine Biological Association
M.R.	Preston	Liverpool University, Oceanography

29 April, 8 - 14 May 1988

D.	Flatt	Proudman Oceanographic Laboratory

8 - 14 May 1988

T.	Jickells	University of East Anglia, Environmental Sciences
H.J.	Kitts	Plymouth Polytechnic, Marine Studies
C.J.	Ottley	Essex University, Chemistry
P.J.	Statham	Southampton University, Oceanography
A.D.	Tappin	Southampton University, Oceanography

SHIP'S OFFICERS

G.M.	Long	Master
B.	Richardson	Chief Officer
T.	Morse	2nd. Officer
S.	Bagshaw	3rd. Officer
I.	McGill	Chief Engineer
A.	Adams	2nd. Engineer
A.	Greenhorn	3rd. Engineer
P.	Edgell	Electrical Engineer (29 April - 8 May)
R.	Macdonald	Bosun

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CRUISE OBJECTIVES

Preparatory to the survey experiments of the North Sea Programme.

1. To test the proposed cruise track (Figure 1).

2.1 Along the track to make continuous measurements of

a) Sea surface temperature, conductivity, transmittance, fluorescence and incident irradiance.

b) Atmospheric inputs.

c) Current profiles.

2.2 At sites along the track

a) To record CTD profiles of temperature, conductivity, transmittance, fluorescence, dissolved oxygen and up- and down-welling irradiance.

b) To obtain water samples with a rosette sampler for calibration of the CTD sensors and for nutrient and trace metal analysis.

3. To obtain sufficient cores to enable the benthic fluxes experiment to select six representative sites where measurements will be made during the survey cruises.

4. To deploy and recover four moorings at 52 30N 2 25E.

5. To test the instrumentation, techniques and methods to be used during the survey cruises, including the shipborne computer.

6. To train people to operate the equipment; a mid-cruise port call at Tynemouth will enable the exchange of personnel.

7. To extend the survey data set (August 1988 - October 1989) by obtaining data in May 1988.

PLAN

29 April	: Sail from Great Yarmouth, deploy four moorings at 52 30N 2 25E. Return to Great Yarmouth to exchange personnel by boat.
29 April - 8 May	: Complete the survey track in the Southern and German Bights and along 55 30N from Denmark to England.
8 May a.m.	: Exchange personnel off Tynemouth, by boat if circumstances permit.
8 - 13/14 May	: Complete the remainder of the survey track - off the east coast of England, Dogger Bank and off East Anglia, including several box cores off the mouth of the Humber Estuary.
13/14 May	: Recover moorings; mooring trials.
15 May a.m.	: Dock at Great Yarmouth.

The following measurements were planned whilst steaming round the survey track: -

1. Surface

a) Position, water depth, ship's speed and heading.

b) Incident total irradiance (port and starboard).

c) Sea surface temperature, conductivity, fluorescence, transmittance.

d) Acoustic doppler current profiles.

e) Atmospheric fluxes

29 April - 8 May. Bulk aerosols for trace metal and trace organic analysis.

8 - 15 May. Large aerosols and precipitation.

2. At stations 10-20 miles apart.

a) Profiles against depth of temperature, conductivity, transmittance, fluorescence, up- and down-welling irradiance and dissolved oxygen with a CTD.

b) Water samples for nutrient analysis with an autoanalyser, for filtration to determine the suspended sediment load and for salinity determination.

c) Water samples for trace metal analysis (8 - 15 May)

3. At stations about 50 miles apart, cores with the SMBA multiple corer.

NARRATIVE

RRS Challenger sailed from Great Yarmouth at 07.00 29 April 1988 and arrived at the mooring site (52 30N 2 25E) at 13.00, having stopped for 45 minutes at 11.30 to wire test two acoustic releases. Four moorings
were deployed - a spar marker buoy, by 13.07; a thermistor chain on a 7895
single point 1/2" chain mooring with a 6 ft diameter toroid as a surface
buoy, by 13.42; an acoustic doppler current profiler in a pop-up sea bed 7896
frame, by 14.47; and two S4 and one Aanderaa current meters in a pop-up 7897,8,9
mooring with a dummy ground line by 16.38. At 20.40 RRS Challenger was back off Great Yarmouth where the pilot boat was used to exchange E. Cooper for D. Flatt.

A course was set for the mouth of the Rhine, starting the survey track (see Figure 2 for the cruise track). Equipment was brought into operation and logged as and when ready. The following were immediately available:-

Ship's position, speed (e-m log) and heading. The position as determined by Satnav was logged; it had been hoped to use main chain

Decca but there were formatting difficulties with the output from the bridge Decca unit - a problem which is expected to be solved by the start of the survey in August.

Surface total irradiance (port and starboard).

Sea surface temperature and conductivity, via a thermosalinograph and the up-rated non-toxic supply. This latter provided a plentiful supply of water for all the surface measurements. The intake is underneath the ship, about 4.5 m below the surface.

The ship mounted acoustic doppler current profiler. It was set to record 10 minute averages and 4 m depth bins throughout.

At 07.00 30 April the first core was obtained with the SMBA multiple corer and at 09.00 the first CTD profile, by which time the ship was steaming westward towards the mouth of the Thames. The multiple corer worked well throughout the cruise, with few problems. The CTD system was relatively new and also worked well throughout although three problems (actual or potential) were identified, relating to its size, to the water bottles and to the near bottom echo sounder. Its suite of sensors (temperature, conductivity, transmittance, fluorescence, up- and down-welling irradiance and dissolved oxygen) provided much fascinating inter-disciplinary information.

The pole for the overside transducer for the Simrad echo sounder was deployed at 12.50 but vibrated excessively as soon as the ship picked up speed. The distance between the bracket which fitted into the shoe on the ship's side and the transducer was reduced to 2 m and an extra bracket was attached near the top to the gunwale. After these modifications the pole was deployed at 17.17 and worked well throughout the cruise. Even so it is not a satisfactory arrangement, since the pole must be lifted inboard before mooring recoveries and pilot boat exchanges / docking - a hull transducer would be much simpler and give better quality data. Logging of the depth started at 13.00 1 May, by which time the ship was off the Rhine again. The Plymouth Polytechnic transmissometer was now working too and by 16.00 so were the RVS surface transmissometer and fluorimeter. The full set of sensors was now up and working.

Steaming round the survey track continued along the Dutch and German coasts, reaching Helgoland by 07.00 on 4 May (CTD 41). The transect parallel to the Danish coast was completed by 18.00 on 4 May (CTD 47, Horne's Rev) and the northern boundary (along 55 30N) by 18.00 on 6 May (CTD 72). For operational reasons the transfer of personnel off

Tynemouth was brought forward by a day, so a short excursion only was undertaken, 5 CTDs near the Farne Islands and Holy Island. Tynemouth was reached at 08.30 on 7 May (CTD 79), where the pilot boat was used to exchange personnel (G. Bradshaw, E. Cooper, D. Hydes, W. Miller, J. Parkes and M. Preston left and D. Flatt, T. Jickells, H. Kitts, C. Ottley, P. Statham and A. Tappin joined). The exchange was completed by 10.30.

Progress around the survey track continued, zig-zagging southward along the English coast into Tees Bay (CTD 87) and towards the Humber. The water bottles dedicated to trace metal sampling were brought into use and the same problems experienced. The 'roughest' weather of the cruise was experienced for a short while on the morning of 8 May (force 6) but was not sufficient to test either the robustness of the equipment or the operational methods. Paradoxically by the afternoon of 8 May RRS Challenger's speed was reduced because of fog (in fact fog caused more delays to the cruise than rough weather). The mouth of the Humber was reached at 22.00 and a box core attempted at 55 33N 0 27E for the trace metal / estuary plume studies. Since the sea bed was unsuitable - a mixture of sand, gravel and stones - a core could not be recovered.

The next 3 1/2 days were spent completing the offshore measurements in the Dogger Bank region, arriving back off the Humber at 06.00 12 May (CTD 141). Because so little time had been lost during the cruise a detour was arranged up the Humber estuary, for which a pilot was required, to take 5 CTDs and several box cores. A suitable box core was taken within the estuary but none were obtained at the mouth, where muddy sea floors had been expected. The pilot was picked up at 08.00 and left at 12.15. The Wash was visited (CTD 149, 18.00 12 May) and the mooring site reached at 06.00 13 May.

The pop-up current meter mooring was recovered by 08.06 (hitting the bottom of the ship during the mooring's ascent after release) and the pop-up acoustic doppler by 10.14. It took 1 1/2 hours to switch on the doppler's acoustics and the instrument tubes appeared to have been covered in sand - the site is in an area of sand waves. The thermistor chain was recovered by 11.11. The current meter rig was then redeployed by 13.00 and recovered by 14.26, as an exercise to gain familiarity in turning round the S4s. No data were recorded by the S4s during the first deployment, presumably because of a lack of experience with the PC based set up procedure. Data were recorded during the second deployment. The marker buoy was recovered by 15.24. 5 extra CTD profiles were recorded off the Dutch coast during the night of 13/14 May and RRS Challenger docked at Great Yarmouth at 18.30 14 May.

Aided by fine weather the cruise achieved all seven objectives listed above. The survey track was completed and shown to be feasible in good conditions, any fine tuning to the track will be determined solely on scientific grounds. The operation of all the equipment was tested and although all worked well, as expected, minor modifications are proposed in the following reports to improve performance or handling. The new SUN workstations performed their data logging tasks well, but further development of the system is needed, especially in the production of plotted output. 164 CTDs were recorded and 41 cores recovered with the SMBA multiple corer. Very little time was lost because of rough weather (more was lost because of fog), to some extent a disappointment in that the effects of rough weather on the equipment and on handling it were not experienced.

INDIVIDUAL PROJECT REPORTS

CTD equipment and rosette sampler (R. Powell, W. Miller)

164 CTD profiles were recorded, see Table 1 and Figure 3.

The CTD (Neil Brown MkIII) incorporated the following additional sensors - dissolved oxygen, transmittance, fluorescence and up- and down-welling irradiance - together with a 10 KHz beacon and a command beacon. A rosette sampler containing twelve 10 l General Oceanics GO-FLO water bottles was attached to the top of the CTD frame. Since the CTD is central to the survey it is of paramount importance that at least two experienced CTD shift leaders are aboard each survey cruise to cover all watches through a 24 hour operation.

All the sensors on the CTD frame appeared to function correctly. The temperature values were confirmed against two new digital reversing thermometers and a good match always obtained. The CTD salinities were confirmed by measuring the salinity of samples with an onboard Auto Sal. The Auto Sal worked well and is ideally situated in the dark room. The transmissometer readings were calibrated against samples (see the Suspended Sediment section below). The fluorimeter, dissolved oxygen and up- and down-welling irradiance sensors behaved satisfactorily.

The new deck unit sometimes hung up. Pressing the reset button reinitialised the system. This happened very rarely and mostly after rosette bottle firing. It was not a particular problem and could easily be ascertained by observing the changing numbers on the monitor screen.

The monitoring package in the main laboratory worked well; only minor changes being needed. Bench space will need reallocation with the addition of another 19" rack to make the systems better suited to incorporate the computer's Level A.

The winch behaved well. Communication with the winch driver relied on VHF handsets. The batteries went flat on these handsets a few times during the cruise, resulting in the loss of communication - potentially dangerous. A second set of two handsets would be sensible. A wire out and rate indicator in the main laboratory is necessary.

The near bottom echo sounder initially used on the CTD was not satisfactory for North Sea work. The blanking period was too long to monitor approaches to within 2 m of the sea bed, as required, and the 2 s repitition rate was too slow. A 10 KHz beacon was used instead and proved satisfactory. The Precision Echo Sounder on the ship functioned correctly. Its use is fundamental to the safe operation of the CTD. The command beacon on the CTD (required if the package is lost) was successfully tested.

The GO-FLO water bottles were a disappointment (see also the Trace Metals report). Considering the system was new, their operation gave nothing but trouble. The main reason for this was the poor workmanship in manufacture and the obvious lack of quality control before dispatch. Attempts were made to improve their operation but things are still not right. Sometimes the confirmation switch on the rosette sampler deck unit did not turn on successful firings. No reason for this was discovered.

The CTD frame was large and heavy but performed its function well. The suspension point needs to be raised by six to nine inches to facilitate setting up of the GO-FLO bottles. A further look is needed to find suitable 'buffers' for the frame to protect the side of the ship. The 'buffers' need to be 'non pollutant' to trace metal work, strong and not to impede standing on the frame to cock the bottles.

There was not much working room around the CTD deck position under the side 'A' frame. A series of cleats and eyes are required with appropriate ropes and hooks to make the CTD deployment safer. An open gate in the bulwark would also help, or perhaps a low wall, so that the heavy CTD frame does not have to be lifted over the full height of the bulwark. It would be ideal if the door of the Fish Laboratory opened the other way because it impedes CTD operation. It is also important that a good working team of three people plus winch driver be available for deployment. It can be a hazardous operation with the weight of the frame swinging about in rough weather.

Surface sampling (R. Powell, W. Miller)

The surface profiling equipment consisted of two off total surface irradiance meters, two off transmissometers, fluorimeter, thermosalinograph and echo sounder. All (except for the transmissometer in the Plymouth Polytechnic housing) were logged on the shipborne computer. The surface irradiance meters and the transmissometer in the RVS housing were not monitored on chart recorders. On the North Sea Project proper there will also be two off IMER PAR sensors.

There were inadequate means for monitoring these instruments. A chart recorder is needed for each variable - three more dual pen chart recorders fitted in a 19" rack would fulfil the requirement.

The new non-toxic seawater supply was used for the deck transmissometers, fluorimeter and thermosalinograph. This proved very successful in the amount of water supplied but unfortunately the de-aerator was not near enough for the job. Air bubbles which entered the system in heavy sea conditions affected the transmissometer readings. The fluorimeter was seemingly unaffected. The thermosalinograph was also unaffected but this was due to its header tank which also acted as a 'bubble remover'. Header tanks should be fitted to the transmissometers and fluorimeter - the feasibility of this can be tested on Cruise 31 in July. An injection system is needed at the non-toxic input (in the engine room) to inject detectable soluble materials into the flow so that the delay time through the pipes can be determined. This is important together with the ship's speed in determining the position of the sample.

Both transmissometers functioned well except when air bubbles were in the system. As the readings in the Humber Estuary were zero it is suggested that a shorter pathlength transmissometer be purchased to magnify the scale in such areas. The thermosalinograph, fluorimeter and and total solar irradiance meters worked well. The irradiance meters need to be mounted on gimballed supports each side of the ship's monkey island so when one is in a shadow the other is not. A similar system will be required for the IMER PAR meters.

The Simrad depth sounder functioned correctly throughout the cruise, although there were many errors on the digital readout, which also provided the signal which was logged. It would be useful to have a digital readout in the main laboratory. The overside pole carrying the Simrad transducer proved to be a nuisance. It was taken in and out many times throughout the cruise to facilitate boat change-overs and rig retrieval. A hull mounted Simrad transducer is needed for the North Sea exercise. The paper drive should also be disconnected or switched out as a hard copy of depth is not required when data are being logged.

Suspended Sediment (T. Moffat)

The objectives of the cruise were:-

1) To test all instrumentation, techniques and methods for the measurement of beam transmission and the concentration of suspended material.

2) To obtain vertical and horizontal (surface) profiles of beam transmission using the transmissometer systems mounted on the CTD and within the flow of the ship's non-toxic water supply. To collect water samples for the calibration of the transmissometer data.

Results.

1. Transmissometers. One Sea Tech transmissometer was mounted on the CTD frame. Two further Sea Tech transmissometers were installed in water jackets mounted on the deck and then plumbed into the newly upgraded non-toxic water supply with de-aeriator and flow meters.

During the cruise all the transmissometers performed well except for the deck-mounted ones during periods of stormy weather. Pulses of tiny air bubbles were observed entering the Plymouth Polytechnic water jacket (perspex) as the ship pitched and rolled. The air bubbles were seen to pass through the light beam of the transmissometer and this created considerable noise in the transmissometer signal output. Although it was not possible to see into the RVS water jacket, it was likely that a similar phenomenon was occurring. As a temporary measure the non-toxic supply to the Plymouth Polytechnic water jacket was redirected through the header tank of the thermosalinograph which resulted in the total removal of the air bubbles and a major improvement in the signal to noise ratio.

Agreed actions. RVS to investigate the feasibility of installing header tanks to the two deck-mounted transmissometer water jackets. There is need for header tanks as the present de-aeriator does not appear to be working efficiently (if at all).

RVS is also requested to supply graph recorders for both the deck-mounted transmissometers as continuous records of beam transmittance from both are required.

2. Water Sampling. No serious problems were encountered in obtaining water samples from the rosette sampler or from the non-toxic water supply to the transmissometer water jackets. Water samples for filtering were collected at the following CTD stations:- 1-69, 81, 84, 87, 90, 93, 96, 98, 101, 104, 107, 111, 114, 117, 120, 126, 130, 135, 137, 139, 141, 145 - 156, 159 - 164. Additional water samples (20) were collected directly from the non-toxic water supply.

3. Filtration System. The filtration system was set up on the bench space provided in the Fish Laboratory. Unfortunately this laboratory is unsuitable in its present arrangement for conducting filtrations because

(i) The bench space lies directly beneath an air conditioning outlet.

(ii) The door to the outside deck remained open during the cruise to give ready access for CTD deployment.

(iii) The Fish Laboratory was filthy and was used as a 'rubbish tip' by others.

(iv) The Fish Laboratory acts as a social meeting point ('tea room'). Sometimes it was very difficult to gain easy access to equipment because of chairs and bodies.

The first three items are major sources of contamination (e.g. airborne particles, dust, dirt etc.) which will affect the filtration experiments. It is absolutely necessary for the sake of good scientific practice that the condition of the laboratory is improved. Other than the problems with the Fish Laboratory, the filtration system and procedures went very well except for a few minor difficulties (e.g. clogging and/or tearing filters, condensation). It was most encouraging that other people quickly learnt how to operate the equipment and carry out the routine filtration procedures.

Agreed Actions. RVS has agreed to look into the condition of the Fish Laboratory. It was suggested that the filtration system in a modified form be contained within a laminar flow cupboard to minimize the effects of contamination. It was also suggested that the Fish Laboratory could be partitioned off into two areas, one for the filtration equipment.

Nutrients (D.Hydes)

The new RVS automated continuous flow nutrient analysis system was used on Challenger 28 for the first time. The system consists of a five channel 'Chemlab' analyser configured for the determination of low levels of ammonia, nitrate, nitrite, phosphate and silicate in seawater. Analyser output is linked to an IBM PC based data reduction system. The system was delivered directly to the ship from Barry and set up prior to sailing for the first time. For this cruise three channels were used nitrate, phosphate and silicate. Determinations were made only on samples collected by water bottles at each of the CTD stations. Subsamples were collected in 30 ml polystyrene vials, which were stored between a half and twelve hours in the dark before being analysed. During the survey cruises samples will be taken by continuous sampling of the ship's non-toxic supply, in addition to sampling by water bottles.

In general the system worked well and no major problems were encountered. Samples were successfully analysed from each of the 164 CTD stations, and samples were also set aside to test sample stability. All the data were logged on the IBM PC, data transfer to the main computer archive has yet to be arranged. The density of data collected was sufficient for successful contouring. The spring bloom was well established during the period of the cruise and this is reflected in the low levels of nutrients determined. Higher levels were encountered in areas of lower salinity water adjacent to river inputs. An interesting contrast is seen in these waters between the eastern side of the sea where nitrate concentrations only were high in the low salinity waters and the western side where all three nutrients were high. At the moment it is not known if this is due to differences in input or a biological effect. The high concentrations encountered near estuaries increase the work load in this part of the survey as samples need to be diluted to bring them into the measurement range of the analyser.

Requirements:

(1) Domestic 4 C refrigerator under the forward bench in the wet laboratory, adjacent and to the left of the sink, for the storage of samples.

(2) Large chest type 4 C refrigerator in the hold for the storage of liquid chemical reagents for the analyser.

(3) Access to the non-toxic supply should be mounted below and to the right of the forward bench in the wet laboratory. Connection will be by hose clamped onto 1/4" fitting.

(4) The taps should remain removed from the wet laboratory forward bench.

(5) Access for 4 hours/day to a second PS2 compatible computer with 3 1/2" 1 M disc drive, for checking the data before logging.

Atmospheric inputs (M. Preston, T. Jickells, C. Ottley)

The atmospheric deposition component of the North Sea Project aims to determine the input of various contaminants to the North Sea from the atmosphere via shipboard collections of aerosols and precipitation. Four separate projects are involved; two from Liverpool University involving the collection of bulk aerosols, one from the University of Essex involving analyses of large aerosol particles and one from the University of East Anglia involving precipitation. On survey cruises two people will run all four experiments, on the shakedown cruise each group ran its own experiments. Liverpool personnel were on leg 1 and UEA and Essex personnel on the second leg.

Trace inorganics and organics (first leg).

There were two principal objectives during this cruise.

1) To test the equipment installed for the collection of high volume aerosol and cascade impactor samples.

2) To collect samples for trace metal and trace organic analysis for the purpose of establishing typical concentrations of these components and therefore permitting a suitable sampling strategy to be established. All analyses to be carried out on return to Liverpool.

Results. Equipment consisting of three pumps (in a waterproof housing), a hoisting system for a filter plate and a mount for the cascade impactor housing was constructed and installed by RVS personnel prior to sailing from Great Yarmouth. These were situated on the deckhouse top area.

No significant mechanical or electrical problems were encountered with the main equipment installations but two separate noise problems were identified. One was the exhaust noise from the pumps and the second was a resonance set up in the deckhouse structure which caused unacceptable noise problems in the deckhouse / forward crew quarters areas. The two noise problems combined to make it necessary to restrict operations during the cruise to daylight hours (Captain's instructions). These problems will have to be corrected to allow 24 hour operation during the main cruise programme.

Agreed Actions.

1) Liverpool to investigate the possibility of ducting the exhaust gases away from the direction of the bridge deck forward cabins. If

technically feasible, the exhaust systems will be constructed with integral orifice plates to reduce the amount of effort required to make flow measurements on a regular basis. Some form of trestle support will also need to be built for the exhausts.

2) RVS to remount pump box on dampers to reduce vibrations and to adjust the conduit carrying the power supplies accordingly. Collaboration between RVS and Liverpool will be essential because the the pumps must not be operated without the filter plates in place and these will have to be supplied by the Liverpool laboratories. The possibility of some Liverpool personnel sailing on the Barry - Great Yarmouth passage leg prior to the the first survey cruise in August so as to be able to install / test noise reducing equipment will be investigated.

3) RVS to investigate the possibility of installing a small hand winch on the deckhouse top to assist in the raising of the filter plate.

4) RVS/ship's electrician to re-route and put in conduit the 240V AC mains cable supplying the University of Essex vacuum pump box and which is at present trailing in the deckhouse top deck in an area where it is frequently trodden on / tripped over.

5) RVS to re-paint filter plate with epoxy paint.

6) Crew / RVS to obtain and install bottlescrews to allow proper tensioning of the filter plate stabilising stays.

Other problems identified

1) Lack of light on the deckhouse top at night. There are problems here with the night sight of the Officer of the Watch. Torches may be the only practicable option.

2) Safety lines will be necessary for safe work on the deckhouse top in rough conditions.

3) Meterological data is a very important component of the atmospheric sampling programme and a system for logging this data automatically would be a great advantage. For this particular project true and relative wind speeds and directions are the most important parameters but other projects (e.g. those of Dr T. Jickells (UEA) and Dr R. Harrison (Essex)) may well have additional requirements. On the shakedown cruise meterological data had to be logged by hand and this was made additionally complicated by the fact that the wind-direction repeater unit in the plot was not working thereby requiring frequent visits to the main unit on the bridge.

4) Laminar-flow cupboards: There should have been two laminar-flow cupboards on the ship for the shakedown cruise whereas only one was present. In general a laminar flow cupboard is essential to the atmospheric sampling group on all survey legs and must be available in either the main laboratory area or in the general chemistry container if installed. When the ultra-clean container is on board there will be one laminar flow cupboard in it but a second one must be available for use outside this area.

5) Some discussions have revealed a possible conflict of interest between the atmospheric sampling group and other groups over the use of the anchor. The SMBA multi-corer can only be deployed successfully if there are no strong currents present and the ship is able to maintain station over the corer. In adverse conditions it is possible that the coring group may request that the anchor be dropped in which case there potentially a problem of contamination of the foredeck area, where the atmospheric samplers are situated with metallic dust from the anchor chain. This can probably be solved by lowering the anchor slowly whilst hosing it with water, but it is something that needs to be noted.

6) During the cruise the condition of an oil leak from the outer stern tube gland appeared to deteriorate rapidly. On a number of occasions when the ship was on station the drift carried the vessel backwards over the point of release of the oil causing the oil to enter the intake for the new non-toxic supply. This oil apparently passed through the sensor chambers and was released with the escaping water over the side. On a number of occasions a slick was noted drifting over the point of deployment of the CTD with a serious risk of badly contaminating both sensors and water bottles. This matter needs to be dealt with as a matter of urgency not only because of the problems that it could cause to the scientific programme but also because such releases are unacceptable in principle from an environmental research vessel.

General note. So as to be able to monitor the sampling equipment effectively, and to ensure some natural justice over the matter of noise, it would seem sensible to arrange that, wherever feasible, the atmospheric sampling group occupy the forward facing bridge deck cabins (5 or 6).

Conclusions. This was generally a successful shakedown cruise though the relatively calm weather meant that the ruggedness of the exposed equipment could not be fully evaluated. A useful set of samples was collected (six pairs of filters for each of the inorganic and organic analysis and two cascade impactor samples) but at the time of writing these have not yet been fully analysed but this should be completed prior to the first cruise in August.

Rainwater collection.

The collection of rainfall for major and trace inorganic components at sea is a difficult task because of the need to minimise contamination from both the ship and seaspray. The collection system used is relatively simple involving plastic funnels screwed to plastic bottles supported in plastic holders. The system is deployed covered in a plastic bag which is removed when it is raining. During the shakedown cruise samplers were deployed at four locations, one on the forepeak 20 foot aft of the bow, two on the deckhouse roof one to port and one to starboard and one on the bridge roof. Detailed evaluation of the system was restricted by the lack of rain with only three rain events, two of which were light drizzle. However, even this limited sampling opportunity proved valuable.

The first rain (8/5/88 06.30-09.00) was accompanied by a relatively strong head wind and rough seas.The bow collection position was not opened and during the opening of the deckhouse roof collectors a wave broke over the operator. Seasalt levels in rain collected on the deckhouse collectors were at least 10 times those on the roof of the bridge.

It is clear that the forward three positions are not useful in heavy weather and it is proposed to move routine operations further aft to minimise spray problems, though such a move increases the risk of contamination from the ships structures and stacks. The best compromise identified is to mount collectors on the outside of the ladders from the bridge wings to the bridge house roof. One of these sites should be exposed to clean rain from any sector within ninety degrees of the bow, should reduce the risk of contamination from the ship and seaspray and also be relatively simple and safe to man. A somewhat easier option of the bridge wings themselves is not acceptable because of wind eddies and problems with obscuring the ship's navigation lights.

A second problem encountered was that much of the rain on this cruise was in the form of very light drizzle which is very hard to collect from a boat. However, since we must maximise the number of events to be sampled we will attempt to develop modified collectors which will sample more efficiently under these conditions. The first option will be to try to enlarge the collector funnels but special collectors for cloud water or simply large plastic sheets may be used. These mist conditions are often associated with very light winds and under these conditions we would attempt to sample at the bow.

Action Required: RVS will provide a bracket to go on the outside of each bridge wing ladder to hold two rain collectors (one for acids and one for metals). RVS to plastic wrap all rigging forward of the bow that can be wrapped (aerials may be impossible to wrap) particularly the two main wires between the masts. RVS to fit a short pole (about 1 foot high on the bow to take samples when conditions permit. Also any modifications to the air sampling gear on the deckhouse should not result in contamination of the bridge wing area, particularly redirection of air ducting. UEA to consider redesigning and enlarging collectors.

Other observations;

1. Laboratory space (minimum about 4 fet by 3 feet) adjacent to the laminar flow clean cupboard will be required throughout all survey legs for the atmospheric deposition group.

2. In order to predict sampling operations the posting of weather forecasts (both shipping for wind speed and direction and conventional for rain) would be useful. Also a display of the ship's position and future track is needed so that relative wind directions can be predicted and collectors opened or closed as appropriate. Shipboard logging of wind speed and direction is also required.

3. During the shakedown cruise atmospheric deposition personnel stood four on eight off CTD watches. During periods of intermittent rain this could become difficult to maintain if collectors are being constantly opened and closed. Thus it may be necessary occassionally to allow some flexibilty in the system. Ultimately rain collection may be sufficiently routine to include it within conventional watches.

4. Dr Preston's suggestion that atmospheric inputs personnel be allocated cabins 5 or 6 would offer a further advantage in allowing the operators to be able to see their collectors and the weather approaching.

Therefore, although the opportunities for rain collecting were very limited, the cruise was basically sucessful in identifying areas where we can improve our operations prior to the start of the survey.

Large aerosol collection.

The objectives behind the second leg of the shakedown cruise were to test equipment and experience sampling conditions first hand.

Results. The equipment consists of an electric fan in a wind tunnel with an isokinetic cascade sampler differentiating between large and small particles:- 20 micron and larger, 20 - 8, 8 - 4, 4 - 2, 2 - 1, 1-0.5 micron, along with a backup filter. As the equipment was partially constructed the wind tunnel was unable to face into the wind and consequently suffered from contamination from the ship's rigging and smoke stacks. Also isokinetic conditions were not established at the inlet of the wind tunnel. Thus as the samples obtained would not be representative of actual aerosol levels it was decided to run the equipment continuously to see if it could operate for prolonged periods in the marine environment. The equipment proved satisfactory except for the vacuum pump. This tended to overheat and its thermal cutout mechanism operate. This was minimised by periodically opening the weather-proof box.

Actions. Even though the equipment was not fully operative a great deal has been learnt, which will enable the final wind tunnel to be constructed so as to minimise the problems encountered above.

1) Due to rigging and ship's exhaust the sampler will operate in the forward port quadrant with switches defining the angle, connected to a data logger recording sample time.

2) Decide on criteria to switch off equipment. In the event of precipitation equipment must be switched off, while sea spray is more subjective but again water should not enter the impactor.

3) The pump box will be redesigned by RVS to facilitate cooling. This will require the user to alter the vacuum pump to electrical specification IP 56.

4) Check with RVS about the placement of fuses or solenoids.

5) A clean air bench was lacking but is essential and must be available on later cruises. The user will require access for a few hours every 3-4 days.

Numerous minor problems were encountered but all can be overcome.

Conclusion. Many problems have been identified but most are easily rectified. The final wind tunnel will incorporate a few modifications which have been realised on this cruise. Considering that the equipment was not fully functional the cruise can be considered a success as it brought to light many problems which will be solved, via modifications of equipment etc., prior to the start of the North Sea Project sampling period proper.

Acknowledgements. We should like to acknowledge the considerable assistance that we have received from RVS personnel in constructing and setting up our equipment and also the skill and helpfulness of the officers and crew of RRS Challenger which greatly contributed to the success of our cruise.

Trace metals (P. Statham, A. Tappin, H. Kitts)

The main objective of the shakedown cruise was to set up and test systems for the collection of dissolved and particulate samples for trace metal analysis. These systems will be used in the surveys as well as during specific process studies (estuarine plumes; bloom- trace metal chemistry), to give samples which will provide information on a suite of metals including Al, Cd, Cu, Ni, Mn, Pb, and Zn.

1) Clean Chemistry Container. As the clean container had not been used for trace metal work for some time and had also recently undergone a refit, a large effort was required to clean and recommission the facility. In addition to the general preparation work, the cartridges for the Milli-Q water supply were replaced, and the laminar flow hood was reinstalled. Nitrogen gas was piped to the container from cylinders positioned on the after winch deck. Checking the cylinder pressure (to monitor usage and leaks in the system) proved inconvenient, and the use of smaller cylinders, one of which could be positioned in the ante-room of the container, will be explored. Reaching the top of the bottles when they were mounted on the side of the container proved difficult. A step about 500 mm high should be located in front of the left hand bottle rack; such a step was constructed by RVS for the 1986 use of the container in the Indian Ocean.

2) GO-FLO Sampling bottles. Seven of the most recent set of 10 l GO-FLO bottles purchased by RVS had been specially adapted and cleaned for trace metal work. These bottles proved to be a major source of problems during the shakedown cruise. Of the 7, only 4 worked satisfactorily without further work. One bottle lost a handle during recovery early in the cruise, and was used as a source of spares as the main body of the bottle was holed. The remaining 2 bottles underwent extensive modifications over a period covering some 40 CTD stations. The major problems related to the rotation of the end balls, and the water seal obtained. In several instances poor machining and tolerances on components appeared to be contributory factors. Both bottles eventually were made to work using spare components; intercomparisons between

unaltered and these modified bottles were undertaken to check that the latter were still suitable for trace metal work. The problems mentioned above with this set of bottles are considerably worse than those experienced with the previous set of GO-FLOs purchased by RVS in 1986 and used for the first time in the Indian Ocean that year. However, given the current situation, the investigation of alternative makes of bottle which may be suitable for trace metal and general applications is recommended.

3) Sampling seawater for subsequent trace metal analysis. The main mode of sampling was with the CTD rosette. Samples taken using the GO-FLO bottles were transferred to the exterior of the clean container, and the seawater was piped into the laboratory where it was pressure filtered through an inline 47 mm diameter membrane. The filtrate was acidified to preserve the sample. In total, 35 samples were collected by this method during the cruise. The basic system (using functioning GO-FLOs) operated well, although it will not be until some of the metal analyses have been performed in Southampton that we will be sure that there has not been any contamination of the samples. The collected particulates were stored for later analysis. A few large volume filtrations were carried out using 142 mm diameter filter units. The small and large volume particulates which were collected were stored for later analysis.

A limited number of samples were taken using a clean hydroline system. This consisted of a Kevlar line with an epoxy coated lead bottom weight. The line was deployed using a small winch mounted on the aft side of the midship's winch "A" frame. The comparison of samples taken using this and the CTD system will help to demonstrate the suitability of the CTD system for trace metal sampling under these conditions. The Kevlar system also provides a backup to the CTD for obtaining samples for trace metal analysis. A davit currently partly obscures access to the starboard rail where the bottles are recovered from the Kevlar line, and this should be removed before trace metal sampling cruises if possible.

It was intended to deploy an underway surface sampling system suitable for trace metal work. However, time was not available to set this system up, and this will be tried on a subsequent leg.

4) Large volume particulate sampling. Large volume water samples are required so that sufficient particulate matter is obtained for subsequent trace metal analysis using atomic absorption spectrometry. The metals to be analyzed for are As, Hg, Cu, Ni, Zn, Mn, Fe, and Co.

A large pressure filtration unit was used, taking 142 mm diameter membrane filters and discrete samples of up to 4 l at a time. The samples were piped from the GO-FLO bottles to the unit, which was situated in the ante-room of the clean room. Flow rates through the system were investigated using Millipore, Sartorius and Nuclepore filters. Using Millipore filters only, six samples were taken approaching and in the Humber Estuary. With the water being very turbid, only 8 l samples were required.

The RVS 142 mm diameter filter system was used to take large volume samples direct from the GO-FLO bottles. It is hoped to use this system in order to reduce the possibilities of contamination and to make the results from the dissolved and particulate trace metal sampling more compatible. However, with filtering large volumes there may be some problems with settling of particles in the GO-FLOs - an outlet modification may overcome this.

5) Sediment work. The trace metal content and the degree of methylation of arsenic and mercury was to be investigated in the sediments off the Humber Estuary. A series of 5 cores, at 2 km intervals, between a dumpsite location and the coast was planned. The box corer was to be used and subsamples in small plastic tubes taken from this. On coring at the dumpsite and at two nearby locations only stones and coarse gravel were found, indicating that fine material dumped in this area is moved away.

In order to test out the box corer in a sandy environment, a core was taken in the Humber Estuary near Grimsby. This type of coring disturbs the surface layer of the sediment, and so using a different type of corer will be looked into. One core was extruded from its tube whilst inside a nitrogen tent. Samples from the surface and anoxic zones were leached using either 0.1M nitric acid or a 25% acetic acid / hydroxylammoniun chloride reagent. The leaches were then filtered a day later, and the metals in solution will be measured at Plymouth Polytechnic.

6) Sampling for other chemical analyses

In order to provide an indication of the validity and stability of the dissolved oxygen sensor on the CTD, a limited number of discrete samples were taken for later analysis at SUDO. Data will be sent to Robin Powell at RVS. Samples were also taken for later dissolved organic carbon analysis.

Benthic fluxes (J. Parkes, A. Upton, J. Watson)

Objectives.

1) To test core sampling gear (SMBA Multiple Corer and Craib Corer).

2) To collect undisturbed sediment samples of a range of sediment types and from the widest possible geographical area on the cruise track, for basic analysis (particle size, organic matter content, depth of reduced zone, pore water chemistry, porosity etc.) which will enable six permanent survey sites to be selected.

3) To test modified equipment and new analysis techniques, including modified core tubes for the multiple corer, micro-oxygen electrodes and oxygen uptake equipment.

4) To determine rates of sulphate-reduction at selected sites to assist in site selection and to adapt the technique for North Sea sediments and use on board ship.

5) To collect sediments for Dr. Assinder (UCNW) and Professor Murray (Exeter University) for collaborative studies.

Progress made on Leg 1.

1) Sediment cores were obtained at all sites (Table 1, Figure 4) using the multiple corer, except on one occasion when the corer was pulled out of the sediment at an angle due to the ship drifting from position in strong currents. Adjustments to the corer were made throughout the leg to enable a full compliment of cores of the required depth to be obtained. The modified core tubes worked well. Problems were experienced with the smaller Craib Corer, and although after small modifications the corer was working correctly, collection of samples was still inconsistent. This may be a reflection of a combination of strong bottom currents and compact sediments. However, the multiple corer will be used in the main survey with a box-corer as a back-up system.

2) Core samples were obtained from approximately three sites in each 24 hour period. These sites were evenly spaced along the cruise track to obtain maximum variation in sediment type and good geographical coverage. Samples for particle size, porosity and organic matter content were collected at each site and the physical appearance of the sediment recorded (e.g. sand or mud, depth of reduced zone etc.) and temperature profile with sediment depth measured. A wide range of different sediment types was obtained, these included coarse and fine sands, sandy clays, clays with stones and gravel, muds and different combinations of these. The majority had indications of anaerobic activity below surface, and a large number had a definite sub-surface

aerobic:anaerobic interface. This general situation was found in both sands and muds. Pore water samples, for chemical analysis, were obtained from all sediments tested using combined filtration and centrifugation.

3) The computer controlled stepping motor and data logging system for inserting the oxygen microelectrode into the sediment at known intervals and collecting the data seemed to work well on board ship, although the sytem requires some more development. The system could not be tested with a working electrode as this was broken on board but the tests with an intact but non-working electrode demonstrated that the electrode could be inserted into the sediment without being broken. A prototype electrode for measuring oxygen-uptake from intact cores was found to have problems and no results were obtained. The water bath and temperature control system for oxygen-uptake, however, seemed to work very well.

4) Rates of sulphate-reduction were measured at the majority of sites, and there seemed to be no problems adapting this technique for use on board ship. The real assessment of this technique, however, will depend on laboratory analysis of the incubated samples.

5) All the samples requested by Dr Assinder and Professor Murray were obtained.

Progress made on Leg 2.

Sediment cores were obtained from all sites as planned and brought the total number of sites sampled to 41. The samples on this leg were dealt with in the same manner as those in the first leg. With a total of 41 sites sampled, it should now be possible to choose six permanent sites for the main survey cruises. The second leg produced slightly worse sea conditions, but no difficulty was experienced in handling the Multiple Corer over the stern. One item which should be mentioned here on the grounds of safety is the fact that it is impossible for the main winch operator to see exactly what is happening on the after-deck because of the siting of the large container-laboratory. This proved dangerous on several occasions whilst moving heavy gear around the deck using the crane. Frequently the crane driver had no idea of where the gear was and what obstructions were in the way. Leaking hydraulic oil from the starboard side of the A-frame could be a hazard in rough weather and could also cause problems if any hydrocarbon analyses were being undertaken.

Recommendations

1) If the ship drifting from position causes coring problems during the survey cruises, the possibility of anchoring the ship during coring will have to be considered.

2) It would be much better for operating the Multiple Corer if the main winch wire was 13 mm rather than the 17 mm now fitted. Using the auxiliary winch with 13 mm wire might be an alternative. It would also be helpful to have a small water hose on the aft deck for washing down the corer and core tubes.

3) A small still for distilled water in the chemistry laboratory would be very desirable. This would also save valuable bench space, as the number of large distilled water containers being used at present would be reduced to one or two small containers. A small drying cabinet for glassware is also required. A few stools in this laboratory, which could be stored under the benches when not in use would be highly desirable.

4) A light in the entrance to the constant temperature room and freezer is essential for safe access during the night.

5) Movable spot lights or an extra fluorescent light over the aft benches in the chemistry laboratory would be very useful especially for work during the night.

6) For effective handling of the samples all the laboratory space used on this cruise will be required for the survey cruises. (This excludes the end section of the middle bench which was used for storage.)

7) It is difficult to open the door of the constant temperature room from the inside and could present considerable problems during bad weather. This needs to be improved.

8) It would be useful to have the two lights on the A-frame facing forward on a separate switch from the two facing aft to prevent glare in the winchdriver's eyes whilst lowering and raising gear. The two facing aft need to be on to permit the wire angle to be observed.

Ship's Performance. Consistent support was provided by the Captain, his Officers and crew, and the RVS support staff and this contributed significantly to the success of the cruise.

Moorings (R. Powell, W. Miller, D. Flatt)

All the rigs were deployed successfully and easily, thanks to the fine weather. On retrieval it was found that for a two week immersion the corrosion was excessive. It is recommended that seizing wire be made from monel (or similar) and that new mooring wires are used for each deployment during the North Sea exercise. Unfortunately the new S4 current meters failed to operate. This was probably due to unfamiliarity of the setting up procedure before deployment, although it has not been established what went wrong. On subsequent tests the S4 current meters behaved properly. The S4 current meters will have to be fitted with lithium batteries for North Sea operation. It is recommended that a Dolphin fish be used for acoustic work because of the shallow seas.

The sea bed ADCP was slow to respond to the acoustic release commands and showed signs of having been buried in the sand up to the instrument tubes. The site is an area of sandwaves and so is not recommended for sea bed packages.

Ship mounted ADCP (R. Powell, W. Miller)

The Acoustic Doppler Current Profiler worked well throughout the cruise. The time run error for the old RDI software still gave trouble with the new software when outputting magnitude and direction in the graphics mode, so VN & VE were output instead. The spare IBM PC was not working properly and was returned to RVS for repair.

Computing (E. Cooper, A. Robinson)

Requirement: Shakedown cruise prior to the 1988/1989 North Sea Programme. Surface sampling, navigation and CTDs. Sea-going trials for the SUN workstations and associated hardware / software.

Method: All data were collected and processed via the Level A, B, C(upgrade) systems including the Cambridge Ring. Standard Level A's were used to acquire gyro, em log, sat. nav., thermosalinograph, decca and CTD data. In addition depth, surface fluorescence, surface transmissittance and total irradiance were logged. In all 29 megabytes of data were collected.

Hardware report:

1) Level A's :- All worked well, except for FLUTE and SOLI which exhibited continuously flashing Rx/Tx lights on occasion and needed resetting.

2) Level B. Crashed a number of times, particularly during the first week. Various attempts were made to trace the cause. On occasions the Level B would still be logging but the monitor display would be hung. Possibly the M2080 console has been the root of the problem, since it was serviced there have been no problems. Towards the end of the cruise the Level B crashed many times during the day though less often at night.

3) Plessey Level C. This sytem was little used, for reference only, with all data being processed and archived on the SUN workstations. For the first few days the system would spontaneously reset. The problem persisted despite a thorough clean but was cleared by exchanging the power supply unit for a spare. It was noted that the replacement unit had a higher current rating than the faulty unit.

4) Cambridge Ring. On day 131 the Cambridge Ring adapter failed, data from the three Level A's in the main laboratory failing to reach the Level B. Resetting the adaptor caused the Level B to crash, reason unknown. Since no spare adaptor could be found the Level A's were wired into the Level B via the junction boxes. One data lead had to be cut up to allow this to happen. One lead seemed to cause problems but when a different set of lines in the junction boxes were used all was well. This probably means that some of the wires (24-27) are faulty.

5) SUN workstations. On first power up, shoebox 0 blew its mains fuse and a replacement fuse. Following which a SUN engineer attended and exchanged the power supply unit and the mains filter. There were no other hardware problems. Two terminal servers have been tried (Micom, Spider). The Ethernet cabling was extended to the main laboratory using two cable lengths of 50 m. Force 6 weather was experienced with no ill effects to the new equipment.

6) Other Hardware. A M220P jet printer, Advance plotter, Lokata printer (for use on Decca or Sat. Nav.) and Marinet were installed. Athough Marconi and RES were in attendance no Marinet communications via satellite were possible because the line kept dropping immediately the remote station answered. This failure was attributed to the Satcom. Marconi and RES were going to persue the problem.

Software Report.

Software transferred from the Uniplus system to the SUN workstations performed as expected for the most part. Apart from GF3 there were no major problems. It was noticed that tick drawing on gridplot produced incorrect results, despite the code being identical to that on the old Level C. The problems with GF3 resulted mainly from bad programming, causing faults which did not show up on the old system, and the use of non standard statuses by bestnav. Optimism as to the ease of transfer to the new system must be offset by the fact that programs that run on the old system perfectly well have in some cases not run on the SUNs, only gross errors such as core dumps and ticks being drawn out of sync are immediately noticeable and a careful watch must be kept out for more subtle errors.

The system coped with all data given to it, CTD data caused no noticeable slowing. This may be different with intensive CTDs but the amount of data in North Sea Project CTD dips (around 800 records per dip) is hardly likely to cause problems. CTD data were processed during dips while other processing / development was carried out. Each CTD dip was given a separate file name ctdrx and ctdpx where x was the station number. The live data were always read into a file called ctd_rvs and processed into a file called proctd_r. At the end of each dip the standard files were renamed and new ones created.

Archiving of data is reasonably fast and because of the amount of data does not take many magnetic tapes (one week's CTD dips = 12.5 hours of data). Unfortunately GF3 took a while to get running. The user interface to GF3 needs looking at, being incredibly tedious to use when large numbers of data files are involved. Two sets of GF3 tapes (four in each) were made for the PSO. Cpio backups were made on half-inch tape for the base along with a tar backup on cartridge.

Bestnav was used for producing navigation (30s navwindow) but with the lack of decca data from the Level A only MX1107 (sat. nav.) was used for input.

TABLE 1. CTD AND CORE STATION POSITIONS

CORE	CTD	LATITUDE N		LONGITUDE		DEPTH	TIME-GMT	
1		52	13.5	3	41.5 E			
	1	52	11.6	3	26.2 E	30	09.19	30/4
	2	52	15.3	2	50.2 E	42	12.23	30/4
2	3	52	10.2	2	19.8 E	45	16.15	30/4
	4	52	04.6	1	49.7 E	28	20.17	30/4
3	5	51	47.2	1	47.3 E	28	22.36	30/4
	6	51	30.3	1	45.1 E	38	01.19	1/5
	7	51	45.3	2	16.4 E	42	04.02	1/5
4	8	51	44.8	2	59.9 E	33	08.00	1/5
	9	52	13.4	3	50.6 E	28	14.06	1/5
	10	52	26.2	3	42.2 E	30	15.53	1/5
	11	52	39.2	3	33.6 E	26	17.35	1/5
5	12	52	52.0	3	25.0 E	27	19.30	1/5
	13	53	04.1	3	16.9 E	27	22.22	1/5
	14	53	17.2	3	08.1 E	33	00.14	2/5
6	15	53	30.6	3	00.1 E	32	02.03	2/5
	16	53	32.1	3	23.7 E	35	04.30	2/5
	17	53	33.6	3	48.3 E	36	06.17	2/5
	18	53	33.4	4	11.6 E	32	07.58	2/5
7	19	53	36.8	4	35.4 E	30	10.11	2/5
	20	53	47.8	4	35.0 E	40	12.19	2/5
8	21	54	06.0	4	35.1 E	46	14.58	2/5
	22	54	20.2	4	35.5 E	49	17.19	2/5
9	23	54	35.0	4	35.7 E	51	19.17	2/5
	24	54	23.1	4	58.6 E	45	21.56	2/5
	25	54	12.9	5	16.8 E	43	23.50	2/5
10	26	54	03.0	5	35.1 E	38	01.53	3/5
	27	53	56.5	5	47.2 E	33	03.50	3/5
	28	53	50.0	6	00.0 E	28	06.24	3/5
	29	53	39.0	6	10.3 E	26	07.04	3/5
11	30	53	43.1	6	30.4 E	22	08.38	3/5
	31	53	55.0	6	25.3 E	28	10.51	3/5
	32	54	06.0	6	25.2 E	35	12.40	3/5
	33	54	20.0	6	24.9 E	40	14.29	3/5
12	34	54	35.0	6	24.8 E	39	16.28	3/5
	35	54	25.0	6	42.7 E	37	18.28	3/5
	36	54	15.0	7	00.5 E	37	20.12	3/5
13	37	54	06.0	7	00.8 E	36	21.42	3/5
	38	54	00.4	7	14.6 E	33	23.18	3/5
	39	53	49.5	7	20.1 E	25	00.57	4/5
14	40	54	11.5	7	27.6 E	38	04.59	4/5
	41	54	16.6	7	44.2 E	26	06.57	4/5
	42	54	25.0	7	40.5 E	26	08.27	4/5
	43	54	37.8	7	32.5 E	26	10.38	4/5
15	44	54	51.0	7	24.2 E	27	12.37	4/5
	45	55	04.1	7	15.8 E	30	14.43	4/5
	46	55	17.3	7	08.0 E	29	16.21	4/5
	47	55	30.1	7	00.0 E	29	18.00	4/5
16	48	55	30.0	6	42.5 E	38	19.56	4/5
	49	55	30.0	6	24.1 E	44	21.38	4/5
17	50	55	30.0	6	06.3 E	50	23.08	4/5
	51	55	29.7	5	48.7 E	51	00.46	5/5
	52	55	29.9	5	29.7 E	53	02.36	5/5
	53	55	30.0	5	10.0 E	43	06.28	5/5
18	54	55	30.0	4	44.0 E	39	08.40	5/5

	55	55	30.0	4	17.9 E	33	11.13	5/5
	56	55	30.0	3	53.9 E	34	13.31	5/5
	57	55	29.9	3	29.5 E	37	15.17	5/5
19	58	55	30.0	3	05.9 E	37	17.57	5/5
	59	55	30.0	2	42.1 E	43	18.57	5/5
	60	55	30.0	2	18.1 E	56	20.45	5/5
20	61	55	29.9	1	54.5 E	68	23.10	5/5
	62	55	30.0	1	29.9 E	70	00.57	6/5
	63	55	29.8	1	11.8 E	71	02.28	6/5
21	64	55	29.8	0	53.8 E	84	04.07	6/5
	65	55	29.9	0	36.0 E	84	05.53	6/5
	66	55	29.9	0	17.5 E	95	07.30	6/5
22	67	55	30.1	0	00.1 W	85	09.03	6/5
	68	55	30.3	0	18.3 W	65	11.45	6/5
	69	55	30.2	0	36.1 W	70	13.30	6/5
23	70	55	29.9	0	54.1 W	98	15.01	6/5
	71	55	29.9	1	12.1 W	89	16.39	6/5
23A	72	55	29.9	1	32.0 W	38	18.14	6/5
	73	55	39.8	1	31.6 W	50	20.00	6/5
	74	55	44.0	1	48.0 W	34	21.36	6/5
	75	55	52.2	1	30.1 W	67	23.38	6/5
	76	55	45.2	1	15.1 W	70	01.23	7/5
	77	55	29.7	1	32.1 W	35	03.37	7/5
	78	55	19.9	1	27.9 W	47	04.55	7/5
	79	55	09.7	1	23.9 W	49	06.11	7/5
24	80	54	59.7	1	14.9 W	54	07.38	7/5
	81	54	58.5	0	55.4 W	73	12.46	7/5
	82	54	56.4	0	35.3 W	65	14.35	7/5
25	83	54	54.2	0	15.1 W	79	16.20	7/5
	84	54	49.0	0	31.1 W	65	18.01	7/5
	85	54	43.8	0	46.8 W	61	19.37	7/5
26	86	54	41.4	0	54.8 W	50	20.43	7/5
	87	54	39.8	0	59.0 W	39	21.50	7/5
	88	54	39.1	0	53.0 W	45	22.49	7/5
27	89	54	39.1	0	33.0 W	58	00.26	8/5
	90	54	39.1	0	13.3 W	70	02.42	8/5
	91	54	39.0	0	07.0 E	78	04.56	8/5
28	92	54	39.2	0	31.2 E	70	07.32	8/5
	93	54	27.8	0	31.4 E	69	09.38	8/5
	94	54	17.0	0	31.3 E	63	11.26	8/5
29	95	54	06.0	0	31.1 E	53	14.22	8/5
	96	53	53.8	0	35.5 E	44	17.39	8/5
	97	53	43.9	0	31.0 E	32	19.53	8/5
	98	53	32.6	0	27.1 E	20	22.05	8/5
30	99	53	30.5	0	41.2 E	93	00.28	9/5
	100	53	35.6	0	50.2 E	19	02.44	9/5
	101	53	35.1	1	14.8 E	25	04.55	9/5
31	102	53	38.7	1	33.2 E	83	06.34	9/5
	103	53	39.2	1	57.0 E	44	08.40	9/5
	104	53	35.1	2	10.3 E	23	10.03	9/5
32	105	53	35.1	2	23.1 E	39	11.12	9/5
	106	53	35.0	2	40.2 E	29	12.46	9/5
	107	53	34.9	2	59.9 E	36	14.26	9/5
	108	53	29.7	2	59.8 E	32	15.54	9/5
	109	53	40.0	2	52.3 E	39	17.26	9/5
33	110	53	50.1	2	44.9 E	34	18.50	9/5
	111	54	00.0	2	37.6 E	65	20.39	9/5
	112	54	10.0	2	30.0 E	58	22.15	9/5

	113	54	20.0	2	22.4 E	32	23.47	9/5
	114	54	29.9	2	14.7 E	19	01.30	10/5
34	115	54	40.1	2	07.3 E	26	03.09	10/5
	116	54	50.0	1	59.9 E	24	04.51	10/5
	117	54	59.9	1	52.4 E	24	06.24	10/5
35	118	55	10.1	1	44.8 E	38	07.58	10/5
	119	55	20.0	1	37.5 E	49	09.56	10/5
	120	55	30.0	1	29.9 E	70	11.56	10/5
	121	55	24.5	1	12.4 E	72	14.35	10/5
36	122	55	18.1	0	54.7 E	72	16.39	10/5
	123	55	12.0	0	37.5 E	82	18.25	10/5
37	124	55	06.1	0	19.9 E	94	20.02	10/5
	125	55	00.0	0	02.5 E	74	21.48	10/5
	126	54	54.0	0	14.8 W	82	23.28	10/5
	127	54	48.9	0	00.0	74	00.55	11/5
	128	54	44.0	0	15.7 E	70	02.30	11/5
	129	54	39.0	0	30.8 E	68	04.07	11/5
	130	54	39.0	0	46.9 E	72	05.38	11/5
38	131	54	39.0	1	02.7 E	50	07.05	11/5
	132	54	39.0	1	18.8 E	38	09.16	11/5
	133	54	39.1	1	43.0 E	37	11.36	11/5
	134	54	40.1	2	07.6 E	28	14.06	11/5
	135	54	24.9	1	45.0 E	45	16.51	11/5
39	136	54	15.1	1	29.7 E	53	18.46	11/5
	137	54	10.3	1	22.4 E	76	20.08	11/5
	138	53	56.7	1	03.2 E	38	22.29	11/5
40	139	53	46.4	0	47.0 E	34	00.46	12/5
	140	53	32.5	0	27.4 E	20	03.52	12/5
	141	53	31.2	0	24.0 E	16	05.51	12/5
	142	53	36.8	0	03.9 W	12	09.43	12/5
	143	53	35.7	0	01.5 W	11	10.18	12/5
	144	53	34.4	0	03.7 E	14	11.00	12/5
	145	53	33.3	0	05.8 E	11	11.33	12/5
	146	53	32.7	0	14.1 E	17	12.32	12/5
	147	53	19.9	0	30.3 E	19	15.36	12/5
	148	53	10.1	0	31.1 E	22	16.55	12/5
	149	53	05.2	0	30.3 E	34	17.57	12/5
41	150	53	13.3	0	47.0 E	20	19.45	12/5
	151	53	01.1	1	03.7 E	15	22.42	12/5
	152	53	01.0	1	26.7 E	26	00.51	13/5
	153	52	39.7	2	10.3 E	37	04.36	13/5
	154	52	29.2	2	25.0 E	52	06.09	13/5
	155	52	30.0	2	25.9 E	50	16.13	13/5
	156	52	25.0	3	00.1 E	36	18.39	13/5
	157	52	19.8	3	19.9 E	31	20.23	13/5
	158	52	07.4	3	28.1 E	31	22.01	13/5
	159	52	13.6	3	50.6 E	23	00.03	14/5
	160	52	21.6	4	00.4 E	25	01.14	14/5
	161	52	29.6	4	10.3 E	27	02.35	14/5
	162	52	37.3	4	20.0 E	22	03.43	14/5
	163	52	37.0	4	00.1 E	28	05.09	14/5
	164	52	36.8	3	46.0 E	31	06.28	14/5

The positions and times refer to the CTD stations (the positions of the core stations are within 1 km of the relevant CTD's).

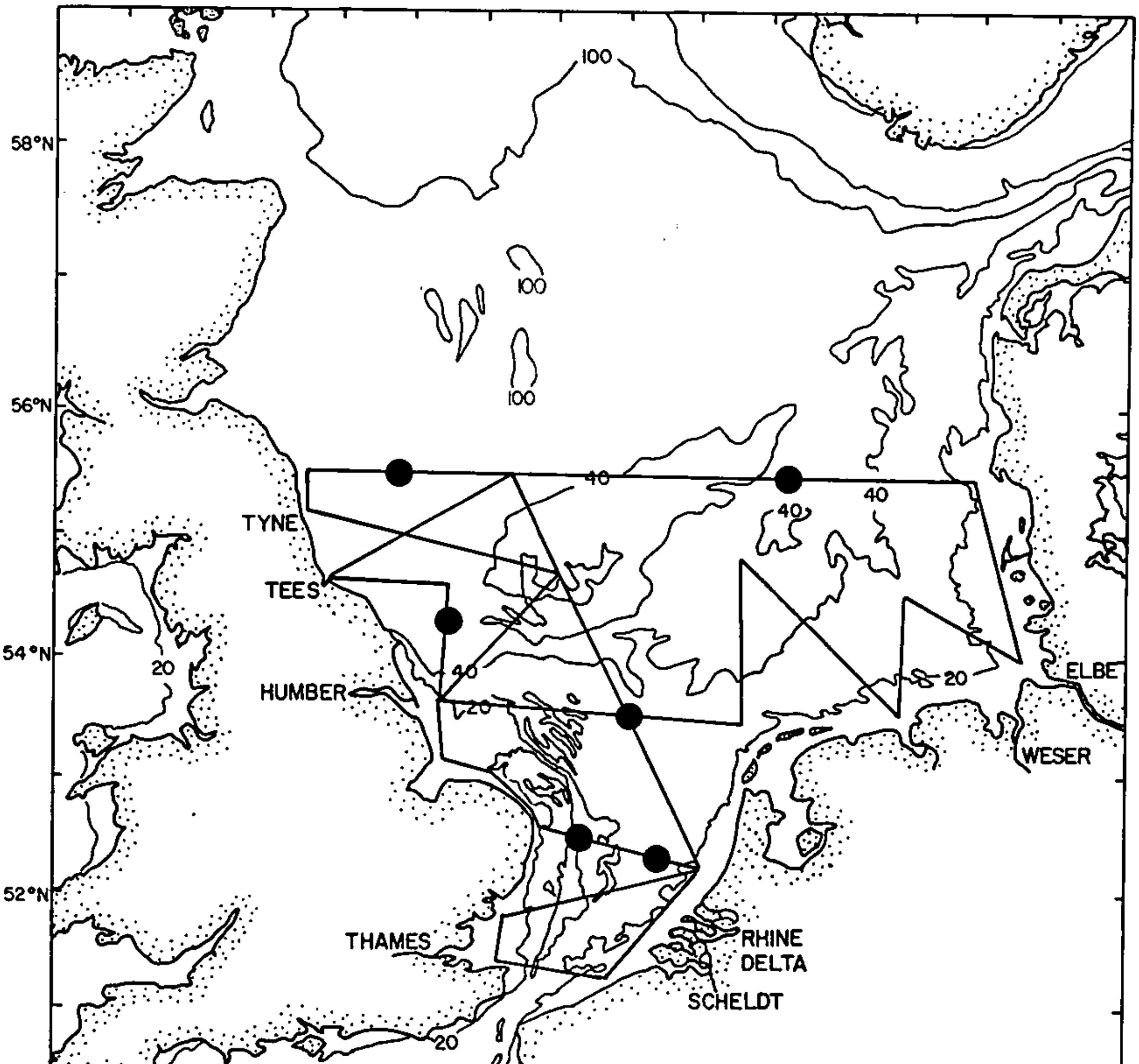

Figure 1. Proposed survey cruise track.

The dots mark the planned mooring sites - apart from the site nearest Great Yarmouth these were not occupied on this cruise.

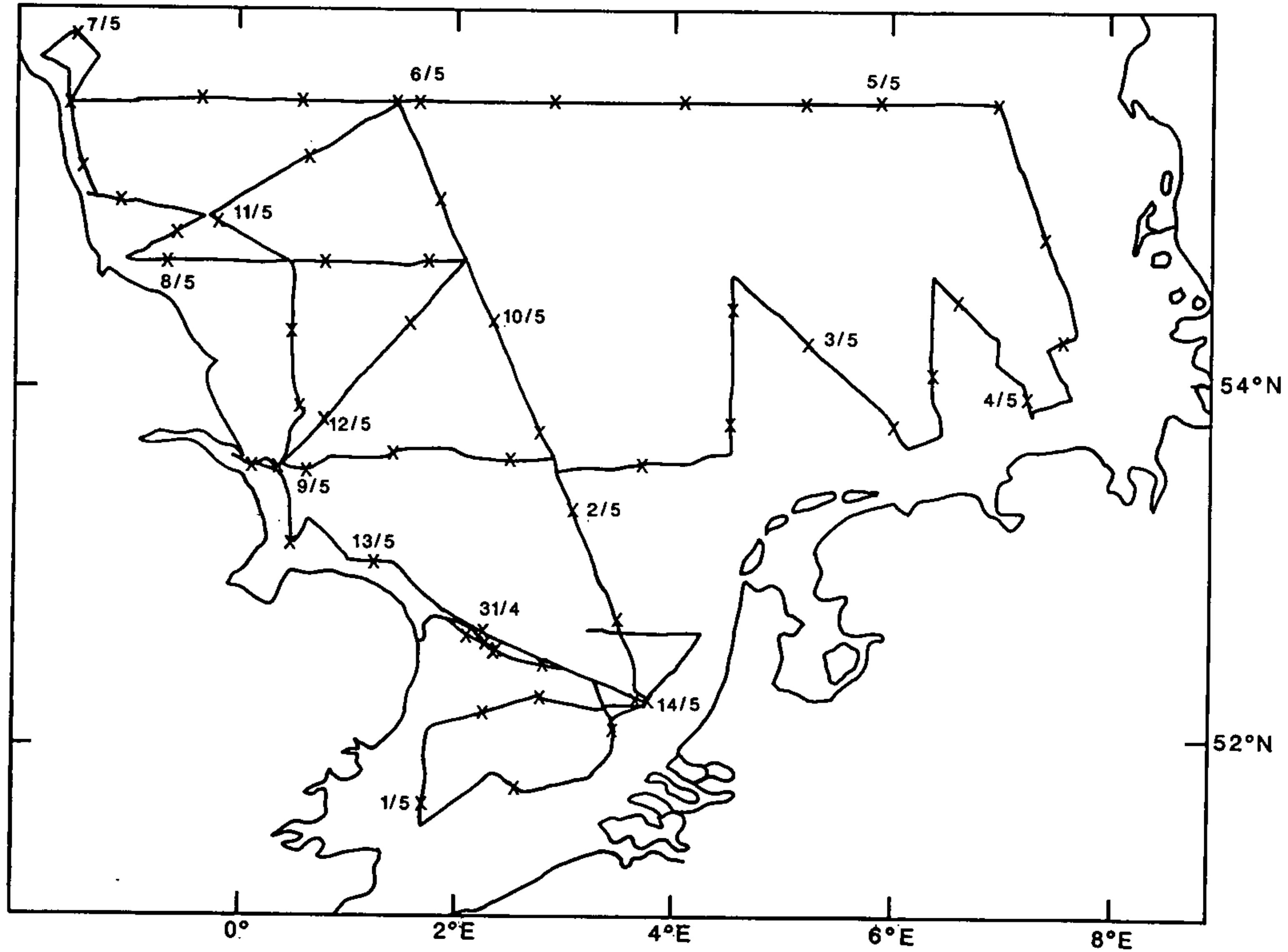

Figure 2. Cruise track. RRS Challenger's position every six hours is shown by a cross.

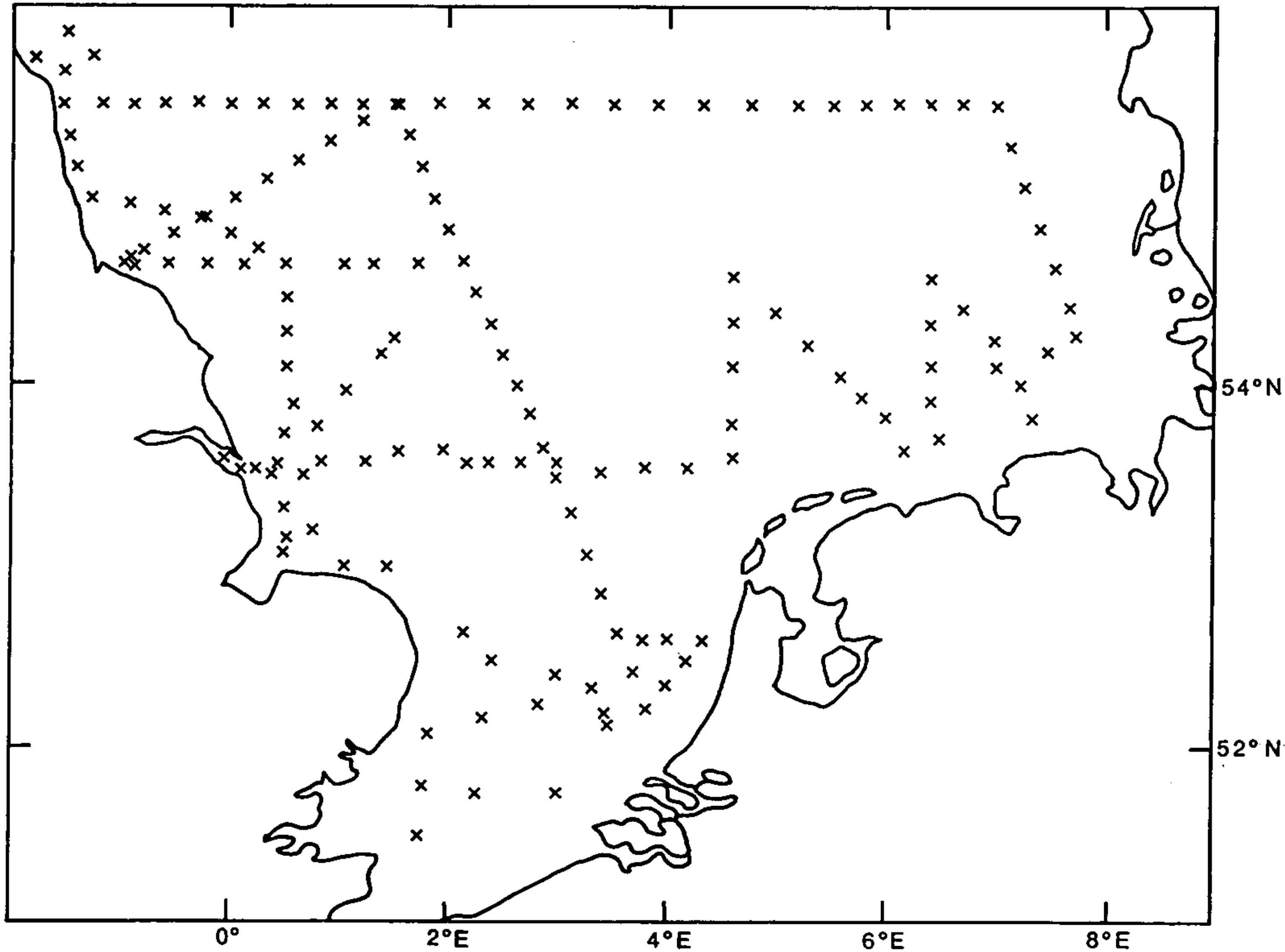

Figure 3. CTD station positions.

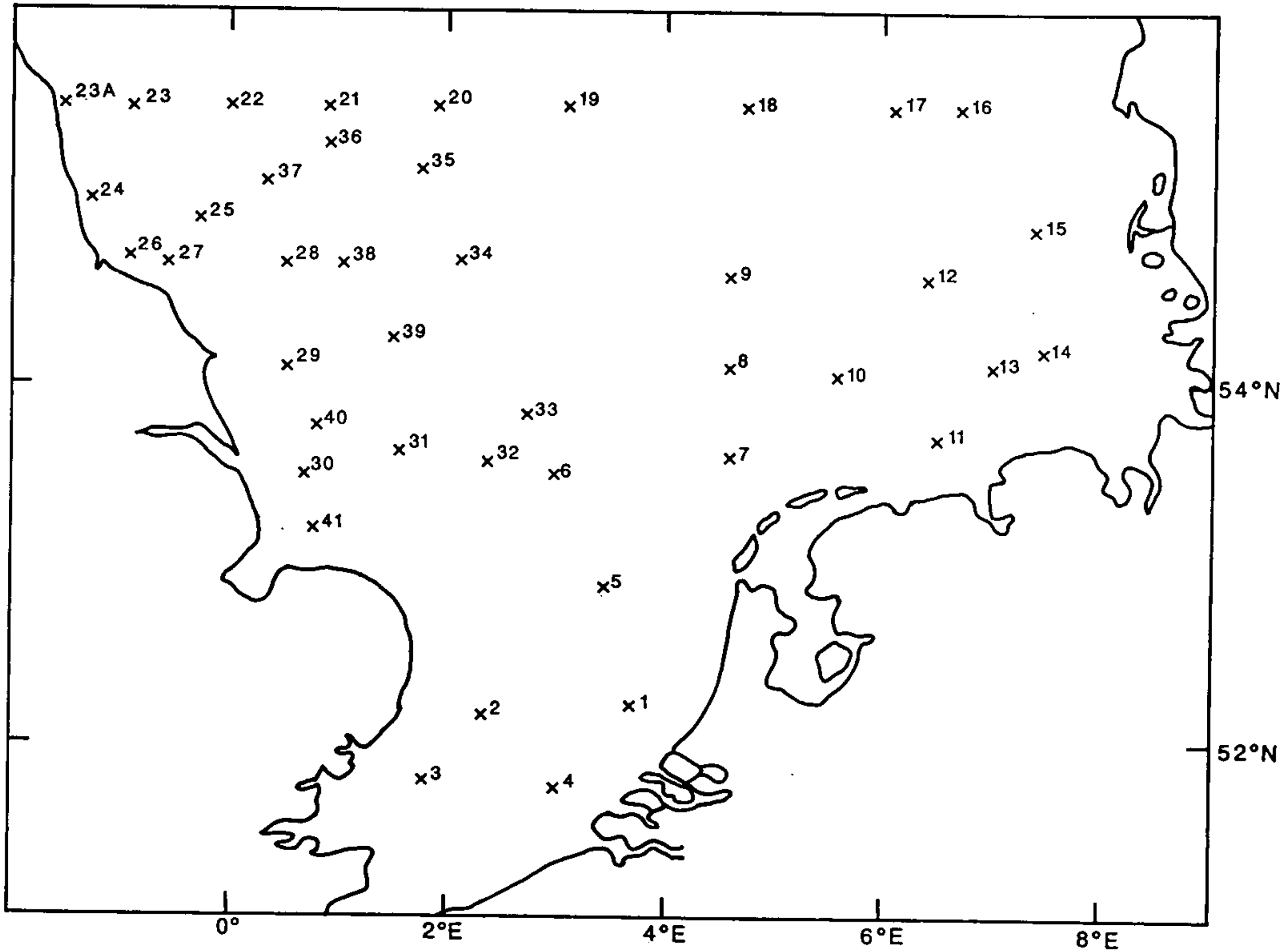

Figure 4. Core station positions.